

SINGLE-GRAIN OPTICAL DATING PROPERTIES OF JSC MARS-1: PRELIMINARY MEASUREMENTS OF RADIATION DOSE RESPONSE AND SENSITIVITY CHANGE. K. Lepper, Luminescence Geochronology Lab, Los Alamos National Laboratory, MS J495, Los Alamos, NM 87545; lepper@lanl.gov.

Introduction: Martian surface deposits, including polar deposits, represent a vast storehouse of data recording the evolution of Mars' climate and surface environment. However, the greatest challenge to deciphering these martian geo-records is the need for absolute dating techniques [1], particularly those techniques applicable to the timeframes and surface processes of the "Martian Quaternary" [2]. Lepper and McKeever [3,4] have proposed developing optical dating, an established terrestrial chronometric dating method based on principles of solid-state physics, for remote *in-situ* dating of martian surface sediments.

We report here the results of ongoing experiments with JSC Mars-1, a terrestrial analog of martian surface materials [5], to establish a broad fundamental knowledge base from which robust dating procedures for robotic missions may be developed. Such data will be critical for determining the engineering requirements of remote *in-situ* optical dating equipments intended for use on Mars.

General principles of optical dating: Over geologic time, ionizing radiation from the decay of naturally occurring radioisotopes and from cosmic rays liberates charge carriers (electrons and holes) within silicate mineral grains. The charge carriers can subsequently become localized at crystal defects leading to accumulation of a "trapped" electron population. Recombination of the charge carriers results in photon emission, i.e. luminescence. The intensity of luminescence produced is proportional to the amount of trapped charge, and thereby to the radiation dose absorbed by the mineral grains since deposition at the sampled site. A determination of the ionizing radiation dose rate at the sample location allows the age of the deposit to be determined (from $Age = Absorbed\ Dose / Dose\ Rate$). Experimentally, optical stimulation can be employed to liberate trapped charge and initiate the measurement process, which gives rise to the name "optical dating".

The event dated by optical techniques is actually the last exposure of the sediment grains to sunlight (i.e. a luminescence age is a depositional age). This is the case because solar radiation, particularly UV radiation, stimulates and removes trapped charge accumulated prior to burial and resets the optical clock.

Because an optical date is a depositional age, the technique is uniquely suited to address questions of chronostratigraphy and climate evolution recorded in sedimentary deposits on Mars. Recent experimental

advances have made it possible to perform optical dating measurements on single sand-sized sediment grains (Fig. 1), paving the way for radical miniaturization and optimization of mass and volume that would greatly facilitate robotic optical dating experiments on Mars.

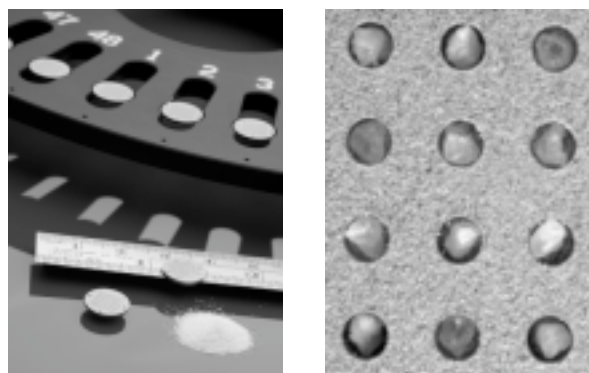


Fig. 1. Single-grain optical dating sample carousel (left) and enlargement of a sample substrate showing individual grains within measurement pits (right) [Image courtesy of L. Bøtter-Jensen, Risø National Lab of Denmark].

Objectives: The goal of this set of experiments is to characterize the radiation dose response, the most fundamental optical dating property, of single sand-sized grains extracted from the JSC Mars-1 simulant. As the measurement process itself can induce changes in signal response from one measurement cycle to the next, these experiments will also, by necessity, characterize sensitivity change.

Methods: A bulk sample of JSC Mars-1 [5] was sieved to obtain the 180-250 μm size fraction and split into two subsets. One remained untreated, the other was treated with HF for 5 min. to remove the iron-oxide grain coatings. The etched sample was rinsed with HCl, dispersant, and methyl alcohol to remove precipitates and particulates and then dried. Dry grains of each subset were placed into the sample substrates shown above (Fig. 1). The substrates were given increasing doses of irradiation from a 40 mCi $^{90}\text{Sr}/^{90}\text{Y}$ beta source (10, 25, 50, 75, 100, 150, 250 Gy) in between which they were preheated to 240°C for 10 s and then measured. Stimulation was for 1 s by a green laser (Nd:YVO₄ - 532 nm) focused on each sample pit with the resulting luminescence being measured in the UV emission range (340–80) by a photomultiplier tube (PMT).

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Results/Discussion: There were several differences between the etched and untreated single-grain sand samples. Observationally, the untreated sample retained its red-brown field color, while the etched sample was predominantly white (presumably plagioclase grains and glass particles) with a very small proportion of black grains (Fe-bearing minerals such as magnetite and pyroxene). Additionally, the untreated grains were statically charged and tended to be repelled from each other and the substrate making it difficult to ensure the substrate was properly loaded with sample grains. Only 1 of the 400 pits of the untreated grains measured yielded signal levels $>2\times$ instrument noise. However, 61 of 400 pits of the etched grains were suitable for further analysis ($>2\times$ noise) -- a data yield of $\sim 15\%$. This data yield difference may suggest that Fe-oxides can act as luminescence "poisons", allowing stimulated charge carriers to be conducted away and/or by absorbing emitted luminescence.

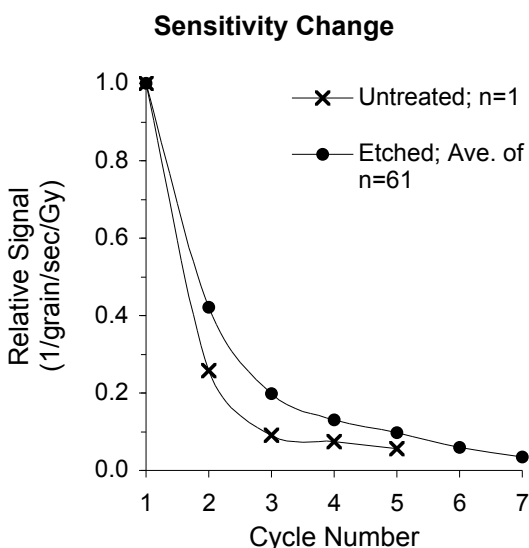


Fig. 2. Observed sensitivity change for the one usable untreated single-grain (x) and the average behavior of the 61 usable etched single-grains (•).

Sensitivity Change. Sensitivity change was accessed from the available data set by dividing the signal intensity observed during each measurement cycle by the dose applied during that cycle (assuming a linear dose response model as observed from a bulk sample of JSC Mars-1 across a wide applied dose range [4]). The results of this analysis are shown in Fig. 2. Both the untreated and etched grains exhibit strongly decreasing signal response with increasing number of measurements made on each grain (cycle #). However, the occurrence of sensitivity change does not in itself negate a material's utility for optical dating. In a

study of fine-grain sediment extracts (4-11 μm) from JSC Mars-1 sensitivity correction procedures, commonly used in terrestrial dating studies, were able to produce dose recovery results within 5% of the expected dose for several sub-samples [6].

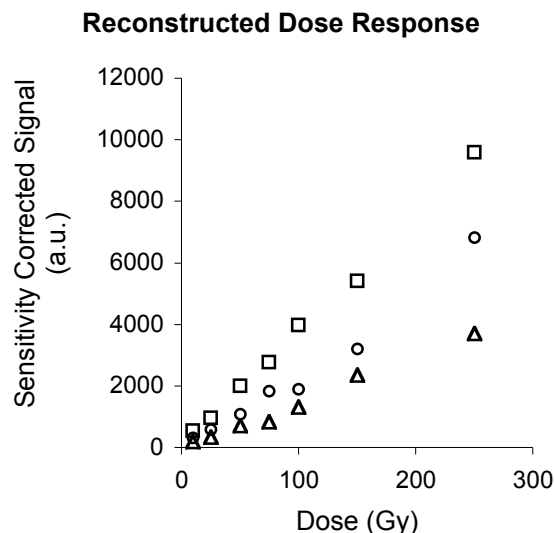


Fig. 3. Reconstructed dose response curves for 3 representative etched single-grains.

Radiation Dose Response. Using the average sensitivity change values obtained for the etched samples (Fig. 2) as correction factors, dose response curves for each of the 61 grains can be reconstructed. Three examples are shown in Fig. 3. Linear regressions of each of the reconstructed curves produced 55 of 61 R^2 values >0.95 , suggesting that the grains exhibit relatively uniform sensitivity change which is adequately represented by the curve shown in Fig. 2.

As stated this method of sensitivity correction can only yield reconstructed dose response curves that mimic the model used for sensitivity analysis, in this case linear. Standard terrestrial single-grain dating methods integrate a sensitivity change correction into the data collection procedures. Results of dose response experiments using this integrated sensitivity correction will also be presented.

References: [1] Clifford S.M. et al. (2000) *Icarus*, 144, 210-242. [2] Edgett K. (2001) *LPSC XXXII*, LPI #1080, CD ROM [3] Lepper K. and McKeever S.W.S. (1998) LPI Contribution No. 953. [4] Lepper K. and McKeever S.W.S. (2000) *Icarus*, 144, 295-301. [5] Allen, et al. (1999) *EOS*, 79(34), 405,408. [6] Banerjee et al. (2002) *Rad. Prot. Dos.* 101, 321-326.